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# The fluvial evolution of the Holocene Nile Delta

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ABSTRACT

The evolution of the Nile Delta, the largest delta system in the Mediterranean Sea, has both high palaeoenvironmental and archaeological significance. A dynamic model of the landscape evolution of this delta system is presented for the period c.8000–4500 cal BP. Analysis of sedimentary data and chronostratigraphic information contained within 1640 borehole records has allowed for a redefinition of the internal stratigraphy of the Holocene delta, and the construction of a four-dimensional landscape model for the delta's evolution through time. The mid-Holocene environmental evolution is characterised by a transition from an earlier set of spatially varied landscapes dominated by swampy marshland, to better-drained, more uniform floodplain environments. Archaeologically important Pleistocene inliers in the form of sandy hills protruding above the delta plain surface (known as "turtlebacks"), also became smaller as the delta plain continued to aggrade, while the shoreline and coastal zone prograded north. These changes were forced by a decrease in the rate of relative sea-level rise under high rates of sediment-supply. This dynamic environmental evolution needs to be integrated within any discussion of the contemporary developments in the social sphere, which culminated in the emergence of the Ancient Egyptian State c.5050 cal BP.



## 1. Introduction

The present Nile Delta is the latest in a long series of deltaic formations, probably going back to the Miocene (Said, 1981). A large amount of research has been undertaken on the Pleistocene and earlier history of the region, mainly as a result of oil exploration (Abu El-Ella, 1990; Rizzini et al., 1978; Said, 1981, 1971; Schlumberger, 1995), but the Holocene landscape evolution of the area remains quite poorly understood in comparison with the rest of the Nile system. In the upper catchment of the White Nile (Cockerton et al., 2015), Blue Nile (Marshall et al., 2011), at the Nile confluence (Williams et al., 2015) and especially through the Egypt-Sudan desert reach (Honegger and Williams, 2015; Macklin et al., 2013; Vermeersch and Van Neer, 2015; Woodward et al., 2015, 2001), much recent work has reported on Holocene landscape succession, relationships between the changing landscape, human settlement and culture, and the varying roles of climatic and other drivers of change in effecting these changes.

It is only the Holocene evolution of the delta's coastal margin that is understood to a level comparable with the rest of the Nile system (Stanley and Warne, 1993a). The evolution of the extensive fluvial plain (approx. 15,000 $km^2$) is less-well known, despite a number of attempts at a delta-wide synthesis over the last century (Bietak, 1975; Butzer, 2002, 1976, 1974; Fourtau, 1915; Hassan, 1997; Said, 1992; Sandford and Arkell, 1939; Stanley and Warne, 1993a, b). This is surprising, given the region's importance in the formative period of the world's first nation state of Ancient Egypt, and its modern-day importance for the nation of Egypt, containing half of the country's agricultural land and population. A better understanding of the mid-Holocene evolution of this area, south of the zone dominated by coastal processes – is urgently needed.

The most recent landscape synthesis of this region (Butzer, 2002) relied solely on lithostratigraphic and chronostratigraphic data collected prior to 1991. Since that time, and especially over the past ten years, numerous teams have carried out geological and geoarchaeological research in the delta, providing a wealth of data on the development of the landscape, none of which has ever been integrated into a delta-wide Holocene landscape synthesis.

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This paper incorporates this recent and ongoing research to provide a new and updated perspective on the evolving mid-Holocene landscapes of the delta, a perspective which needs to be integrated into discussions of the emergence of the ancient Egyptian state, and other sociocultural and economic history studies of the region over the longue durée. The vast deltaic plain was the breadbasket of Ancient Egypt, containing the largest amount of cultivatable land in the country, but without a detailed palaeoenvironmental model its landscape history cannot be truly integrated into a geoarchaeological synthesis (Clarke et al., 2016; Hassan, 2010, 2009; Macklin and Lewin, 2015).

The paper focusses on the time period c. 8000 to 4500 cal BP, as this covers the period of greatest geomorphological change, during which sea-level was approaching its modern-day position (Fleming et al., 1998), and the modern Nile hydroclimatic system was being established, as the "African Humid Period" gave way to more arid conditions (Shanahan et al., 2015). This is also a time period without substantial human factors contributing to and complicating the remodelling of the deltaic landscapes, but is an episode crucial for understanding the palaeoenvironmental context of Ancient Egyptian state formation.

### *1.1. Regional setting*

The Nile Delta is an alluvial plain in the north of Egypt (Fig. 1) constituting by far the largest continuous expanse of agricultural land in the country. Bounded by desert to both the east and west, its apex is at Cairo, where the river divides into two main distributaries: the Rosetta and Damietta, which discharge over the triangular-shaped alluvial plain and flow north into the Mediterranean. Many more distributaries existed in prior time periods (Butzer, 2002; Hassan, 1997), and the apex of the network was also further south (Bunbury, 2013; Lutley and Bunbury, 2008).

The geology of the alluvial plain is relatively simple. The Holocene deposits are mainly represented by a thin veneer of silty sediments of the Bilqas Formation, which lie unconformably on top of the thick, sandy Mit Ghamr Formation (Rizzini et al., 1978), whose top surface comprises the erosion remnant of a buried alluvial landscape formed under a different hydrological regime (Adamson et al., 1980; Stanley and Warne, 1993a). Some of these remnants protrude above the modern delta surface as sandy hills, known as "turtlebacks", or "gezira" (Judd, 1897).

The plain is densely populated and farmed such that little natural vegetation remains. Almost all the water influx to the region is provided by the river Nile. This river displays pronounced seasonality, related to the differing catchments of its three main tributaries. The Blue Nile and Atbara drain the Ethiopian Highlands and provide the majority of the Nile's annual discharge and sediment flux during the Nile flood between July and October, while the White Nile drains Central Africa, provides minor year round discharge but only accounts for 3% of the sediment flux (Woodward et al., 2015). Since the damming of the river at Aswan the Nile through Egypt has not flooded.

## 2. Towards a unified model for mid-Holocene fluvio-deltaic evolution

The Nile Delta developed during a period of decreasing rates of sea-level rise and high sediment supply within the mid-Holocene. Initially, high rates of relative sea-level rise stimulated high rates of floodbasin aggradation, and gave rise to the associated development of a swampy, wetland landscape dominated by the formation of crevasse splays (Fig. 2). High rates of base-level rise would have resulted initially in a reduction of the river gradient, causing a corresponding decrease in energy to transport sediment, and elevated in-channel aggradation rates. These high rates of in-channel aggradation would have in turn led to channel superelevation, since to maintain constant volumetric flow the channels would have built their margins above the surrounding floodplain (Jerolmack and Mohrig, 2007; Mohrig et al., 2000). Superelevation

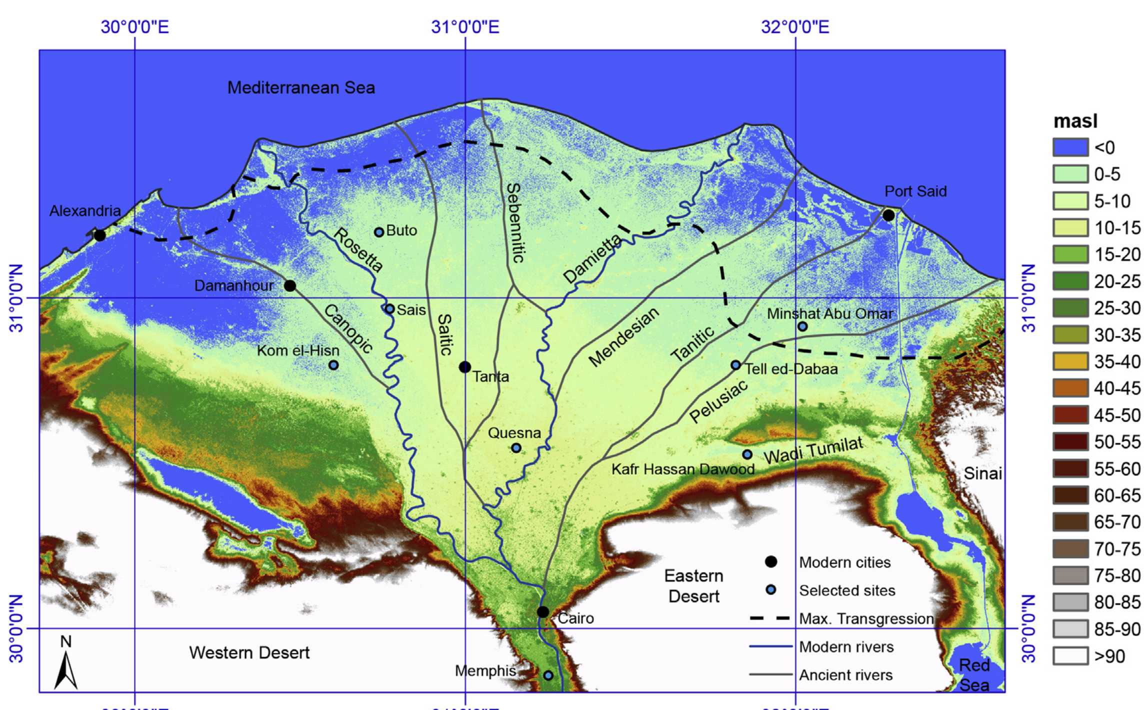


**Fig. 1.** Map of the Nile Delta (SRTM data). The locations of ancient river branches are after Bietak (1975); Butzer (2002); the extent of maximum transgression is as given by Stanley and Warne (1993a). Selected archaeological sites are also shown.